Rate of Water Transport by *Brachidontes exustus*

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It is well known that many lamellibranchs feed on particulate matter, finely dispersed detritus and micro-organisms suspended in the water. Water is pumped through the gills, and suspended material is filtered out and retained. Knowledge of the water transport capacity of the gills is, therefore, essential to an understanding of the quantitative feeding biology and growth of this type of lamellibranch. This investigation will experimentally determine the rate of particle clearance by *Brachidontes exustus* and also examine the effect of temperature on this rate.

Many determinations of water transport through the gills of mussels and oysters in particular, which are of commercial interest, have been made. Both direct and indirect methods of determination have been used. In the direct method the rate of water pumping is measured by the removal of suspended particulate matter from water passing through the gills. The indirect method measures the stream of water leaving the animal by chaneling it into some sort of monitoring device.

Fox et al. (1937) worked out a procedure of indirect measurement. They placed the mussels in suspensions of calcium carbonate and determined the reduction in calcium by doing calcium analyses at various time intervals. Jørgensen (1943, 1949, 1952, 1955, 1960, 1966) and Jørgensen and Goldberg (1953) have used suspensions of algae and colloidal graphite. In the indirect method the organism is put into a known volume of a suspension, and the decrease in concentration of this suspension per unit of time is measured. It is not possible to get a continuous record of pumping this way, and if only a percentage of the particles are retained on the filtering mechanism the rate of water transport measured will be only a percentage of the total amount of water transported. However, as Jørgensen (1949) points out, if the size of food particles in the water is of importance for their retention by the gills, the indirect method offers perhaps, more information directly concerning the feeding biology than does the direct method.

Galtsoff (1926) was the first to devise a direct method. He used a glass tube in the exhalent siphon and a glass rod between the valves to prevent their closing. The water from the exhalent siphon was led into a collecting cylinder and measured. Many modifications of the direct method have followed, most of them involving the use of a rubber dam to isolate the water pumped. A recent method of this type combining the efforts of many earlier workers is that of Drinnan (1964). Hamwi and Haskins (1969) have developed a direct method that does not include the use of rubber cones, the use of which may upset the feeding response of the organism.

The function of the gill as a food retaining filter was postulated over 100 years ago, and is universally accepted today. However, the exact mechanism responsible for particle retention is still not agreed upon. Jørgensen (1966) believes that the latero-frontal cilia act as a sieve. The distance between the latero-frontal cilia in *Mytilus edulis* is about 3 microns. If graphite colloidal particles of 1-2 microns are retained Jørgensen then explains this with MacGinitie's theory. MacGinitie (1941) said the latero-frontal cilia were not important in particle retention. He observed a mucous sheet covering the gill during food intake and believes this mucus is the straining mechanism. Dral (1967) believes the latero-frontal cilia beat is co-ordinated to vary the efficiency of particle retention and that the latero-frontal cilia are sticky; that particles of any size, no matter how small, will stick upon touching a cilium.

While the exact morphological structures and physiological responses are not yet agreed upon, the porosities of various lamellibranch gills are dependent upon many factors (Jørgensen, 1966; Dral, 1967). Temperature, salinity, *p*H, oxygen level, density of the suspension, amount of nutrients present, the way the animals are handled, whether or not they are ovigerous, and condition and age of the experimental animals all effect the filtration efficiency. We should keep this in mind in interpreting any results reported.

MATERIALS AND METHODS

Brachidontes exustus collected from oyster beds near Panacea, Florida, were used in this investigation. They were brought to the laboratory and kept in an aquarium with fresh sea water. The aquarium was aerated and at a temperature of 22 C-23 C. The amount of particulate matter in the water in which they were collected was determined to be 18.4 mg/liter.

Colloidal suspensions of Aquadag, with a particle size of 1-5 microns, and Prodag, with a particle size of 5-15 microns, were used. (Both preparations are manufactured by Acheson Colloids Corporation, Port Huron, Michigan.) The test solutions were prepared by mixing a measured amount of the suspensions in a small amount of distilled water and then adding this to sea water filtered through a 0.45 micron Millipore filter. One liter of suspension was prepared immediately before each test. Each test was carried out in two 600 ml beakers, with 500 ml of suspension in each. Both beakers were aerated continuously and the mussel or clump of mussels were in one beaker only, with the other beaker acting as a control.

The rate of clearance was determined by using a Beckman Model DB-G grating spectrophotometer set at a wavelength of 550 millimicrons, to measure the reduction in concentration of the suspended mixture by the absorbance technique. The spectrophotometer was set to read filtered sea water as 100 per cent transmission. Each suspension was read at the beginning of a test and then four hours later when the test was concluded. Tests were run for four hour periods because while Aquadag and Prodag agglutinate only slowly in fresh suspensions of sea water, they settle out rapidly as suspensions get older.

The data were then used in Jørgensen's (1949) formula to calculate the amount of water pumped per unit time. This formula is most clearly expressed as

$$m = \frac{(\log P_0 - \log P_t)M}{\log e \ t}$$

where m is the quantity of water cleared from particles per unit time, M is the quantity of water used in the experimental vessel, t is the time the experiment runs, P_0 and P_t the concentrations of suspension in the control and the experimental vessel respectively at time t.

The wet weight of the blotted, soft body parts was recorded. The liter/hour rate obtained from Jørgensen's formula was divided by this, to relate the rate of water pumped to body weight. The final rates are expressed as liters/hour/gram.

Tests were run at 22 C$\pm$1 C and at 10 C$\pm$1 C.

Results

Comparing the results of the experiments done at 22 C$\pm$1 C we can see a slightly higher water transport rate shown when Prodag was the colloidal preparation (Table 1).

When the experiments were repeated at 10 C$\pm$1 C we also see a slightly higher water transport rate shown in the Prodag preparations (Table 2).

Discussion and Conclusions

A comparison of Table 1 and Table 2 seems to indicate that temperature change, at least in this range, is not an important factor

TABLE 1

The rate of water propulsion of *Brachidontes exustus* as a function of particle size at 22 C

Prodag concentration in mg/liter	Rate of water transport in liters/hr/gm	Aquadag concentration in mg/liter	Rate of water transport in liters/hr/gm
10	3.8	10	3.6
20	2.9	20	2.9
30	1.5*	30	1.2*
40	1.8*	40	1.5*

*Indicates results from naturally occurring clumps of six mussels each.

TABLE 2

The rate of water propulsion of *Brachidontes exustus* as a function of particle size at 10 C

Prodag concentration in mg/liter	Rate of water transport in liters/hr/gm	Aquadag concentration in mg/liter	Rate of water transport in liters/hr/gm
10	3.5	10	3.3
20	2.9	20	2.7
30	1.2*	30	1.2*
40	1.9*	40	1.7*

*Indicates results from naturally occurring clumps of six mussels each.

in the rate of water transport. This agrees with Loosanoff's (1958) work, in which he studied rates of water transport in oysters between 16 C and 28 C and noted no significant differences. Rao (1953) has reported, however, that there is a higher rate of pumping in mussels with an increase in temperature. In contrast to the mussels used in Rao's work, which all weighed over 1 gm, the mussels in this investigation were all very small, and ranged in blotted wet weight between 13 mg and 30 mg. Size may have some effect on the action of temperature in physiological performance.

Although lamellibranchs are extremely sensitive to environmental changes it has been shown that smaller ones seem less sensitive than larger ones. (Jørgensen, 1960) The mussels, which ranged from 6 mm to 1 cm in length, showed no ill effects when enclosed in relatively small vessels. When they were transferred from the aquarium to a beaker, in no case did it take longer than 10 minutes for them to have byssal threads out, siphons extended and valves open.

It is apparent from Table 1 and Table 2 that the rate of water transport is higher when the concentration of suspension is lower. Loosanoff and Tommers (1948) have shown similar results in *Crassostrea virginica.* It was determined that 18.4 mg/liter of particulate matter was in suspension in the water in which these mussels were collected and perhaps the higher suspension concentrations have a depressant effect on the rate of filtration.

The higher rate of water transport in every experiment run was in the Prodag suspension. Prodag has a higher percentage of large particles than Aquadag, and this indicates that these mussels retain larger particles more efficiently. The exact means of particle retention is not agreed upon, so no conclusion can be drawn from this.

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